UNCLASSIFIED

Defense Technical Information Center
Compilation Part Notice

ADP015040

TITLE: Theory of Skin Depth Interaction of Lasers with Plasmas

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: International Conference on Phenomena in Ionized Gases [26th] Held in Greifswald, Germany on 15-20 July 2003. Proceedings, Volume 4

To order the complete compilation report, use: ADA421147

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP014936 thru ADP015049

UNCLASSIFIED

Theory of Skin Depth Interaction of Lasers with Plasmas

Heinrich Hora[1.2], J. Badziak[3], Y. Cang[2,4] S. Jablonski[3], K. Jungwirth[5], L. Laska[5], F. Osman[2],P. Parys[5],K. Rohlena[5], J. Wolowski[3], E. Woryna[3] and J. Zhang[4]
[1]Department of Theoretical Physics, University of New South Wales, Sydney 2052, Australia
[2]School of Quantit. Methods and Mathemat. Science, Univ. Western Sydney-Penrith, Australia
[3]Institute of Plasmas Physics and Laser Microfusion, 00-908 Warsaw
[4]Institute of Physics, Academia Sinica, Beijing, China
[5]Institute of Physics, ASCR, 18221 Prague 8, Czech Republic

The measured anomalous low maximum energy of ions emitted by TW-ps laser pulses in contrast to ns pulses led to the skin layer interaction model. Consequences are the nonlinear (ponderomotive) force acceleration of plasma blocks against the laser and into the target for a possible alternative laser-fusion scheme.

The measured drastic difference between the maximum ion energies from targets irradiated by TW-ps laser pulses was explained [1] by a skin layer interaction mechanism. This is basically different to the generation of very high ion energies by relativistic self-focusing and implies a very high contrast ratio for the suppression of any prepulse before the main pulse arrived at the target apart from the some pre-irradiation of less than 500 ps before the main pulse. Details of the theory of the involved nonlinear (ponderomotive) force generation [2 of plasma blocks will be reported. The main energy of the laser energy is converted into the fast motion of the two plasma blocks,

- one moving against the laser light and
- the other into the target.

Numerical results indicate that the reflectivity losses are low as long as the von-Laue-type density ripple is moderate as known for longer pulses as the reason for the stochastic pulsating interactions [3]. The block motion of the plasma against the laser light

a) may advantage the application of this operation as laser ion source while the block into the target and
b) is important for application to laser fusion.

For the case (a) a detailed explanation of different plasma groups for longer pulse interaction [4] needed a detailed interpretation. These include relativistic self-focusing as confirmed experimentally ant theoretically in numerous experiments. The second fast group can be identified as due to the generated hot electron as detected from the energetic x-ray spectrum where the thermalization is immediately given by the quantum correction of the collision frequency. This is a proof of mutual agreement of these theories and splendidly explains also recent measurement for ions emitted with 0.6 GeV energy. For further slower ion groups further mechanisms for ion generation [5] were considered. In contrast to theses processes, the (prepulse controlled) TW-ps interaction is very different and simplified as seen from the experiments and as expected from the model of the skin layer laser plasma interaction as expected form the theory of nonlinear (ponderomotive) acceleration and as shown in extensive numerical calculations.

For the process (b) or results is essential that the blocks moving into the target produce ion current densities exceeding 10^{10} A/cm^2 as necessary from the earlier theory of light ion beam fusion. In order to achieve the necessary energy flux density of more than 2×10^7 J/cm^2, the application of shorter laser wavelengths may be interesting. We further studied the need of some prepulse during the last 100 ps before interaction of the ps mail laser pulse in order to receive some swelling of the laser field energy density in the interaction range and for enlarging the effective skin depth as a result of swelling..

Further questions refer to the generation of the fusion reaction front in uncompressed (or low compression) nuclear fusion fuel. These are discussed in view of the recent Nuckolls-Wood model [6] of an electron beam mechanisms for ignition for the fast ignitor. The Nuckolls-Wood scheme needs the usual very high-density pre-compression of DT fuel as usual in the fast ignitor but the basic aim of the PW-ps laser pulse is to produce a very high intensity relativistic electron beam. The physics problems of the relativistic effects are not all e4xploerd yet, even the ele4ctron acceleration mechanism is still open whether it is a wake field acceleration of the "free wave acceleration" which was succesccul to explain recent experiments quantitatively.

In contrast to this Nuckolls-Wood scheme, the nonlinear force produced plasma block ignition excludes the relativistic effects from the beginning, and it does not need the compression of the plasma beyond about ten times the solid state density what process is performed automatically by the one dimensional ablation process of the skin layer process. which conditions may now be applied for the ignition similar to the well known light ion beam fusion.

[1] H. Hora, J. Badziak, F.P. Boody, R. Höpfl, K. Jungwirth, B. Kralikowa, J. Kraska, L. Laska, P. Paris, V. Perna, M. Pfeifer, K. Rohlena, J. Skala, J. Ullschmied, J. Wolowski, E. Woryna, *Opt. Commun.* 207, (2002) 333

[2] H. Hora, *Laser Plasma Physics and the Nonlinearity Principle* (SPIE Books, Bellingham 2000)

[3] H. Hora and M. Aydin, *Phys. Rev.* A45, (1992) 6123

[4] J. Wolowski et al Plasma Physics and Controlled Fusion 44, (2002) 1277

[5] H. Hora, F. Osman, R. Höpfl, J. Badziak, P. Paris, J. Wolowski, W. Woryna, F. Boody, K. Jungwirth, B. Kralikova, J. Kraska, L. Laska, M. Pfeifer, K. Rohlena, J. Skala, and J. Ullschmied, Skin depth Theory explaining anomalous picosecond laser plasma interaction, *Czechoslovak J. Physics*, 52, Suppl. D (CD No.7), (2002) D349

[6] J.L Nuckolls and L. Wood, *Future of Inertial Fusion Energy*, Preprint UCRL-JC-149860 (September 4, 2002) www.llnl.gov/tid/ Library..html